Double spin asymmetry in diffractive $Q\bar{Q}$ production at SMC energies and quark-pomeron vertex structure.

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Abstract

It is shown that the longitudinal double spin asymmetry A_{ll} in polarized diffractive $lp \rightarrow lp + Q\bar{Q}$ reaction depends strongly on the spin structure of quark-pomeron vertex. The SMC spin facilities may be one of the best place to perform such experiment.

At present the study of diffractive processes has attracted considerable interest due to the observation of high p_t jets in diffractive collisions [1, 2]. These events can be interpreted as the observation of partonic structure of pomeron [3]. However this structure can be determined by quarks and gluons. It have been shown in papers [4, 5] that the observes effects can be predominated by quark structure function of pomeron which was confirmed experimentally [2].

Different models are used in investigations of pomeron exchange contribution. First is the BFKL pomeron [6] which is based on the summation of leading perturbative logarithms, second is the nonperturbative model of two-gluon exchange [7, 8]. Such "bare" pomeron exchange leads to the mainly imaginary helicity conserving scattering amplitude because quark-pomeron coupling in this case is like a C=+1 isoscalar photon (see e.g. [8]). So, the analysis of pomeron structure functions using "bare" pomeron is equivalent in some sense to the spin-average quark and gluon distributions inside pomeron.

However the spin structure of quark-pomeron vertex may be not so simple. Factorization of the qq amplitude was shown into the spin-dependent large-distance part and the high-energy spinless pomeron [9]. The quark-pomeron vertex in the semi-hard region $s \rightarrow \infty$, $|t| > 1GeV^2$ [9] where the perturbative theory can be used has a form

$$V_{qqP}^{\mu}(k,q) = \gamma_{\mu}u_0(q) + 2mk_{\mu}u_1(q) + 2k_{\mu}\not{k}u_2(q) + iu_3(q)\epsilon^{\mu\alpha\beta\rho}k_{\alpha}q_{\beta}\gamma_{\rho}\gamma_5 + imu_4(q)\sigma^{\mu\alpha}q_{\alpha}. \quad (1)$$

In (1) $u_i(q)$ are the vertex functions. Note that the structure of the quark-pomeron vertex function (1) is drastically different from the standard spinless pomeron. Really, only the term proportional to γ_{μ} corresponds to the standard helicity conserving pomeron and reflects the well-known fact that the spinless quark-pomeron coupling is like a $C = +1$ isoscalar photon. The terms $u_1(q) - u_4(q)$ lead to the spin-flip in the quark-pomeron vertex in contrast to the term proportional to $u_0(q)$. The functions $u_1(q) \div u_4(q)$ at large Q^2 were calculated in perturbative QCD [10]. Their magnitudes are not very small.

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As a result the spin-dependent quark-pomeron vertex should modify different spin asymmetries and lead to new effects in high energy diffractive reactions which can be measured in future spin experiments in the RHIC at Brookhaven [11] for example.

The obtained structure of quark-pomeron vertex can be detected in $Q\bar{Q}$ diffractive production by the polarized protons. To show this we have been estimated the longitudinal double spin asymmetries in this reaction as an example. The resulting asymmetry can reach $10 \div 12\%$ [12].

However in pp polarized diffractive reactions the obtained asymmetry depends on practically unknown Δg gluon structure function of proton. In order to obtain more explicit results it is better to use lp polarized beams. We hope that the SMC spin facilities is one of the best place to perform such experiment.

In what follows we shall analyse the longitudinal double spin asymmetry for polarized $lp \rightarrow lp + Q\bar{Q}$ reaction at SMC energies which can be detected as $lp \rightarrow lp + 2Jets$ events. The standard set of kinematical variables looks as follows [2] (see fig.1):

$$s = (p_l + p)^2, \quad Q^2 = -q^2, \quad t = (p - p')^2$$
$$y = \frac{pq}{p_l q}, \quad x = \frac{Q^2}{2pq}, \quad \beta = \frac{Q^2}{2q(p - p')}, \quad x_p = \frac{q(p - p')}{qp}, \tag{2}$$

where p_l, p'_l and p, p' are the initial and final lepton and proton momenta respectively, $q = p_l - p'_l$.

In calculations we shall use the hypothesis that pomeron couples to single quark (or antiquark) for simplicity. The integration over all $Q\bar{Q}$ phase space will be performed. We shall omit in calculations the non-log corrections like β that is true in the case when the energy of $Q\bar{Q}$ system is large with respect to the momenta transfer t and Q^2. We shall omit non-log $m_Q^2/|t|$ corrections too. The last simplification modifies numerical results within $5 \div 10$ % accuracy.

The resulting longitudinal double spin asymmetry defined via

$$A_{ll} = \frac{\Delta\sigma}{\sigma} = \frac{\sigma(\overset{\rightarrow}{\Rightarrow}) + \sigma(\overset{\leftarrow}{\Leftarrow}) - \sigma(\overset{\leftarrow}{\Rightarrow}) - \sigma(\overset{\rightarrow}{\Leftarrow})}{\sigma(\overset{\rightarrow}{\Rightarrow}) + \sigma(\overset{\leftarrow}{\Leftarrow}) + \sigma(\overset{\leftarrow}{\Rightarrow}) + \sigma(\overset{\rightarrow}{\Leftarrow})}. \tag{3}$$

The main contributions to A_{ll} asymmetry in discussed region are determined by u_0 and u_3 structures in (1). It can be written in the form:

$$A_{ll} = -x_P y \frac{A_{00} u_0^2 + A_{03}|t|u_0 u_3}{S_{00} u_0^2 + S_{03}|t|u_0 u_3 + S_{33}|t|^2 u_3^2}. \tag{4}$$

where

$$A_{00} = 2Q^2(2 - y)(\ln(\frac{|t|}{m_Q^2}) - 3),$$

$$A_{03} = -Q^2(2 - y)(2\ln(\frac{|t|}{m_Q^2}) - 3), \tag{5}$$

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and

$$S_{00} = 2[2|t|(1-y)\ln(\frac{Q^2}{|t|\beta}) + Q^2 y(2-y)\ln(\frac{|t|}{m_Q^2})],$$

$$S_{03} = -2[2|t|(1-y)(\ln(\frac{Q^2}{|t|\beta}) - 1) + Q^2 y(2-y)(\ln(\frac{|t|}{m_Q^2}) + 1)],$$

$$S_{33} = [Q^2 y(2-y)\ln(\frac{Q^2}{|t|\beta}) + 4|t|(1-y)(\ln(\frac{Q^2}{|t|\beta}) - 1) + Q^2 y(2-y)(\ln(\frac{|t|}{m_Q^2}) + 2)]. \qquad (6)$$

Note that $u_3 < 0$.

It is easy to see from(5) that $\Delta\sigma$ has different signs for light ($m_Q \sim .005 GeV$) and heavy (for charm $m_Q \sim 1.3 GeV$) quarks production. Moreover $\Delta\sigma$ is proportional to Q^2 and σ has a more complicated structure. As a result the asymmetry must increase with Q^2. The obtained asymmetry is equal to zero for $x_p = 0$ and it is better to analyse it at $x_p = 0.1 \div 0.2$.

Our predictions for A_{ll} asymmetry for energy $\sqrt{s} = 20 GeV$ estimated on the basis of perturbative results for vertex functions for $y = 0.5$ and $x_p = 0.2$ for standard quark pomeron vertex ($u_0 z$ terms in (4) only) and spin-dependent quark pomeron are shown in fig. 2,3. On fig.2 the $|t|$ dependence of A_{ll} for fixed $Q^2 = 10 GeV^2$ ($\beta = 0.25$) is shown. On fig.3 one can see the Q^2 dependence of $A_l l$ for fixed $|t| = 3 GeV^2$. The obtained asymmetry is not small and depend strongly on the spin structure of quark-pomeron vertex. For spin-dependent quark-pomeron vertex $A_l l$ asymmetry is smaller by factor 2 because the σ in (3) is larger in this case. Asymmetry decrease with $|t|$ growth and increase with growth of Q^2. It is positive for C quark production and negative for light quark production.

The estimations shows that total integrated cross section of light quark production in lp reaction is about $0.2 \div 1$ nb [4, 13]. Our calculations shows that the cross section for C quark production must be smaller by factor $3 \div 10$.

The discussed here spin-dependent contributions to the quark-pomeron and hadron-pomeron vertex functions modify different spin asymmetries and lead to new effects in high energy diffractive reactions which can be measured in spin experiments at future accelerators.

To summarize, we have present in this letter the perturbative QCD analyses of longitudinal double spin asymmetry in diffractive 2-jet production in lp processes. The model prediction shows that the A_{LL} asymmetry can be measured and the information about the spin structure of the quark-pomeron vertex can be extracted. It should be emphasized that the obtained here spin effects are completely determined at fixed momenta transfer by the large-distance contributions in quark (gluon) loops. So, they have a nonperturbative character. The investigation of spin effects in diffractive reactions is an important test of spin sector of QCD at large distance.

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Figure captions

Fig.1 The diffractive $Q\bar{Q}$ production in lp reaction.

Fig.2 The $|t|$ dependence of A_{ll} asymmetry of light and heavy (C) quarks production at fixed $Q^2 = 10 GeV^2$. Solid line -for standard; dot-dashed line -for spin-dependent quark-pomeron vertex.

Fig.3 The Q^2 dependence of A_{ll} asymmetry of light and heavy (C) quarks production at fixed $|t| = 3 GeV^2$. Solid line -for standard; dot-dashed line -for spin-dependent quark-pomeron vertex.